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Evaluation of the Yield and Organoleptic Quality of Split and Whole Country Style Cured Hams

Nickolas William Norder

EVALUATION OF THE YIELD AND ORGANOLEPTIC QUALITY OF SPLIT AND WHOLE COUNTRY STYLE CURED HAMS

BY

NICKOLAS WILLIAM NORDER

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser — Date

Head, Animal Science Department (acting) — Date

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Any evaluation of carcass or wholesale cut characteristics is generally based upon quality and quantity of lean meat. The quantity factor is of prime importance to the breeder, producer, processor and consumer. Extensive exploration of techniques to increase the relative yield of lean meat in the carcass has been conducted by animal breeders and livestock production personnel. Furthermore, studies concerned primarily with the development of processing methods which increase yield and final product net weight have been undertaken by the meat industry.

Coupled with the quantity factor is the growing concern for product quality. A product with high consumer acceptability should be of adequate quality, yield a high proportion of lean meat, be convenient to use and have a low unit cost. Another important consideration is packaging. A product with high consumer acceptability must be packaged in sizes proportionate to the needs of present day families.

Merchandising whole cured hams is increasingly difficult in today's retail meat outlets because of the following factors: (1) the trend toward smaller family size, (2) increased disposable income, (3) increased weight of hams in today's meat type hog, and (4) housewives are seeking greater convenience in meat items.

Separating hams into smaller units would permit stitch pumping the brine into the ham pieces by machine similar to the bacon pumping method. Pickle could be injected into the parts more rapidly, more

economically, and with a greater degree of control in a constant amount and distribution than could be accomplished in the whole ham. Less space would be required by the split hams in the cover brine, whereas more smokehouse space would be required than is utilized for whole hams.

The basic purpose of the project reported herein was to evaluate the merits of separating whole boneless hams into top and bottom parts prior to subjecting them to the curing and smoking process. Differences in yield and final product quality within pairs, one whole ham and the other separated into parts, were used as indicators of relative merit.

In this study a country style cured ham refers to a salt brine, stitch pumped, 10 day cured ham, without additives, which has been heated and smoked for 23 hours.

REVIEW OF LITERATURE

The following discussion will review factors affecting the yield of cured and smoked ready-to-eat ham from the carcass to the consumer acceptable product. Also discussed will be product quality and its relationship to quantity and processing yields.

Preslaughter Treatments

Most studies concerned with factors affecting preslaughter treatment on fresh meat characteristics have not considered the possible effects in cured products. However, cured product color is directly dependent on the pigment concentrations in the uncured meat.

Hall *et al.* (1961) reported that slaughter plants with resting pens near the killing floor or means of transporting hogs to the floor with little exertion (especially walking) by the animal displayed an advantage in producing sound brine-cured hams with increased water holding capacity and organoleptic traits.

Swine, when forced to exercise continually for 15 minutes 14 hours prior to slaughter, produced hams that were darker and more uniform in color than untreated lots (Rongey *et al.*, 1959). They reported that no significant differences were found between hams obtained from hogs shackled during slaughter and those not shackled.

Pigment variations also occur within carcasses. Ham muscles surrounding the femur contained approximately 1.9 mg. of myoglobin per gm. of tissue while the *semitendinosus* from the same hams contained only 1.2 mg. per gm. of tissue according to Wilson *et al.*

(1959). "Two-toned" is the term applied to ham showing variations of this magnitude. In these experiments a corresponding paired ham showed the same but less marked color variations after curing. A further analysis of the data suggested that the variation in pigment, or the predisposition toward it, was a heritable characteristic. Canadian investigators, as reported by Wilson (1959), noted that cured products from carcasses having a low post slaughter pH retained desirable red color of cut lean surface much longer than did products from carcasses with a high pH post slaughter.

Processing Techniques

Recently Weiner et al. (1966) reported the effect of processing pork carcasses within one hour post-mortem on muscle quality. They showed hams removed from carcasses within one hour post-mortem and pumped with cold brine produced significantly lower total cooking losses and drip losses than hams from sides processed conventionally and chilled at 1.7° C. for 24 hours prior to cutting. Muscles from hams cut hot had significantly lower shear values than the controls.

According to Mandigo and Henrickson (1966) hot processed hams were significantly more tender although the panel found no significant difference in ham juiciness. The authors indicated no significant differences between the yield of hot and cold processing treatments with the shrink averaging 11.5 percent for both treatments. They also indicated that ham could be satisfactorily processed by the hot processing method in less than 15 hours from the time of slaughter.

Delaying the chilling of pork carcasses resulted in lower quality cured meat according to Heck et al. (1955). When pork carcasses remained at room temperature for as long as 4 hours, the skin became dry and brittle and the incidence of ham spoilage in the smokehouse increased. However, when carcasses were chilled promptly after slaughter and held in the chill room for as long as 4 days, there was little, if any, spoilage and no effect on the cured meat. Extending the holding period in the chill room to 168 hours resulted in the loss of external quality in pork carcasses as indicated by dry brittle skin and dark surface color. The internal quality from the same carcasses was not lowered as much. Heck et al. (1955) also indicated that organoleptic traits were higher when a breakdown of the carcasses was completed within 4 days of slaughter and the highest when cutting occurred 24 hours post slaughter.

Curing

Pumping. Rongey et al. (1959) stated that the pressure at which hams were pumped and the number of days in the cure had little or no effect on color uniformity. Although the general rule indicates the addition of 8 to 10 percent of the green ham weight as pickle, the relationship between amount of pickle added to the green ham and factors such as processing shrink and organoleptic traits have received little attention in published research. Industry standards limiting the final water added percentage to 103 percent of the green weight have been set forth in Regulations Governing the Meat Inspection of the United States Department of Agriculture (U.S.D.A., 1960).

Bitter (1951) found that salt distribution in hams injected at 8 or 11 sites by the regional method of "stitch pumping" was equivalent to that in hams cured by the arterial injection method.

Brine Composition. Information concerning length of time in brine and brine composition is generally a commercially patented or guarded secret. Industry standards have been set by the U.S.D.A. (1960) limiting the amount of sodium nitrate or potassium nitrate not to exceed 200 parts per million (ppm) in the product after curing and processing or 2 pounds in 100 gallons of pickle.

With the advent of efficient and widespread refrigeration, the need for preserving meat by curing alone has greatly diminished and factors such as flavor, color, and yield have become of greater relative importance. A textbook by the American Meat Institute Foundation (1960) defined meat curing as the production of the characteristic thermally stable meat pigment and the cured meat flavor by the action of sodium nitrate and other curing agents.

Salt. Salt, one of the basic curing ingredients and important to the final product flavor, has been studied by Wistreich et al. (1960). They found that the salt accumulation value, expressed as sodium chloride diffused into the muscle through one square centimeter of contact area, did not appear to vary significantly between different muscles. Small amounts of sodium nitrate when added to the solution increased the accumulation of sodium chloride. Their studies revealed

that increased brine temperature increased sodium chloride accumulation in a nonlinear manner.

pH. Hydrated calcium lactate and lactic acid when utilized in conjunction with other curing ingredients accelerated salt penetration according to Mullins et al. (1958). They indicated that a weak acid and salt of the weak acid formed a metallic acid ion in solution which served as an accelerator to enhance sodium chloride and other salt penetration. This metallic acid ion also acted as a buffer and stabilized the solution acidity between pH 5.8 and 6.3.

Ascorbates and nitrates were quite reactive at low pH values or at high temperatures. Mullins and co-workers (1959) stated that these compounds were rather stable in high salt concentrations in a pH range of 6.5 to 7.0 when stored under refrigeration. Since a normal brine solution was in this pH range or above, ascorbates and nitrates could be incorporated in chilled brine without forming nitric oxide gas.

Immediately after slaughter pH begins to decrease due to lactic acid formation. Wilson et al. (1959) reported that the lower pH of meat from animals fed and rested prior to slaughter was associated with a more desirable color and improved keeping qualities. The specific point of minimum water retention was also the iso-electric point, pH 5.5, of animal protein.

Deatherage at Ohio State, as reported by Morse (1955), infused a basic solution directly into the blood stream at slaughter to buffer the post-mortem pH at 7.0 and produce protein swelling by salt during

the curing reaction. He reported frozen hams did not drip after thawing.

Hamm (1955) reported that the "phosphate effect" was due to increased pH and salting actions, especially at the raised pH.

Phosphates. In recent years phosphates have been added to meats in an effort to increase the desirability of meat texture, the uniformity of color and the juiciness of cured products.

Beck et al. (1958) indicated it is important not to go above a saliometer reading of 85° using phosphate salts since precipitation of phosphate salt will result. U.S.D.A. limits on phosphate are 5 percent in the pickle and 0.5 percent in the finished product.

Morse (1955), advocating the use of phosphates in curing, explained that pH adjustments of intact meat to the range of 7.0 to 7.4 enabled meat fibers, or protein, to take up and hold their normal water content. On the other hand, meat that approached its iso-electric point (pH 5.5) showed a decrease in water and water solubles. The use of a phosphate salt producing near normal live pH was, therefore, helpful in preventing water loss during processing. Morse also cited work reported by Wilson (1954) in which four phosphate salts used in pumped hams were evaluated. There was no apparent gain in weight, but hams treated with phosphates appeared firmer and drier when cut than did the controls containing no phosphates. Hams treated with sodium tripolyphosphate had the best color of all. No difference in flavor or odor could be detected between controls and phosphate treated hams. Wilson (1954) noted that an advantage, reported by

several packing houses using phosphates, was a reduction in cook-out of juice which can run as high as 5 percent of the retained juice. Also cited was improved color and finally, the hams, though higher in moisture, had a drier appearance when cut than the controls.

Nitrate. The use of nitrite per se in the curing of meats was studied critically by Kerr et al. (1926) and by Lewis and Vose as reported by the American Meat Institute Foundation (1960). As a result of these studies they demonstrated that successful curing may be accomplished by the addition of 1/4 ounce sodium nitrite to each 100 pounds of cured meat. The U.S.D.A. (1960) using these data set its original restriction level which is still in effect today, 200 ppm of sodium nitrite in the finished product.

Hougham and Watts (1958) found that addition of 200 ppm nitrite with no nitrate was optimum for formation and retention of cured meat pigment when treated with gamma rays.

A textbook by the American Meat Institute Foundation (1960) reported the basic curing reaction which results in the cured meat pigment as follows:

myoglobin + nitrite = nitrosomyoglobin

or

myoglobin + nitric oxide = nitricoxide myoglobin

Hollenbeck and Monahan (1953) stated that the reaction of nitric oxide with myoglobin to form the cured meat color (nitrosomyoglobin) during the curing of meat depended upon the hydrolysis of added nitrates. The hydrolytic decomposition of nitrates liberated equimolar quantities

of nitric oxide and nitrogen dioxide. The decomposition of nitrites in the presence of ascorbic acid resulted in the formation of two moles of nitric oxide and little, if any, nitrogen dioxide. Since nitric oxide was the desirable component of the reaction, small quantities of ascorbic acid increased the formation rate of nitroso-myoglobin in the curing process.

A mixed cure is frequently employed on the premise that nitrite will provide a rapid initial cure, and the addition of nitrate will provide a source of nitrite to hold the color upon subsequent storage of the finished product.

Addition of ascorbic acid or sodium ascorbate has been shown by Mullins et al. (1958) to speed normal color development in meat and meat products. This was accomplished by the reduction of metmyoglobin and nitrate to myoglobin and nitric oxide. These compounds then reacted to form the characteristic "cured meat color" nitric oxide myoglobin (nitrosomyoglobin). Ascorbic acid has also been shown to protect cured meat color from fading by Erdman and Watts (1957).

Color

Color, being of first consideration from the standpoint of quality in the final cured meat product, has received major consideration. Experiments have been carried out to determine the physiological and processing factors which may influence color uniformity and stability of cured ham (Rongey et al., 1959). They concluded that high levels of sodium ascorbate in the pickle did not significantly affect color uniformity or stability. Color was also reported to be improved

when hogs were stressed prior to slaughter by either forced exercise or adrenalin injections. Conflicting results reported by Brockman and Morse (1953) demonstrated that the development of the cured meat red color was the result of the action of nitric oxide on hemoglobin and myoglobin. Small amounts of ascorbic acid when added to cured meat enhanced the desirable reactions. Because the oxygenated forms of hemoglobin and myoglobin together with methemoglobin and metmyoglobin are not direct reactants with nitric oxide, their presence and variability introduce variability into the development rate, intensity, and stability of the cured color. Uniformity can be enhanced in the factors cited above not only by increasing the tendency for nitric acid formation from sodium nitrate but also through side effects on the reduction of derivatives of hemoglobin and myoglobin. This concept is supported by the observation that the small amount of ascorbic acid referred to above enhances the rate and extent of color development in ham prepared under commercial conditions. Watts (1957) in support of ascorbate addition stated that the pink cured meat pigment may be lost by (1) reversible conversion into the brown hemochromogen in which iron has been oxidized to the juice state and (2) irreversible decomposition into porphyrin ring split products, green to gray in color. The kind and extent of such pigment changes may be measured spectophotometrically. The first reaction was greatly accelerated by light but inhibited by reducing agents in the presence of nitrite. Protein sulfydryl groups normally supply the necessary reducing agents but these disappeared rapidly at temperatures above freezing. The normal

reducing action may be enhanced by addition of ascorbates. Furthermore, Erdman and Watts (1957) suggested the loss of sulfydryl groups was affected most by storage temperatures while light and types of wrapping paper had little effect. Color fading was affected most by light, but temperature was also important.

Draudt and Deatherage (1956), studying factors which influenced the development and fading of cured meat pigment, found that at least part of the nitric oxide of purified heat denatured globin, nitric oxide myohemochrome, was further oxidized in light and air to yield nitrate and nitrite ions. Nitric oxide from cured meat pigment may be released as a gas, possibly as nitrogen dioxide. Furthermore, a gas, which was absorbed by potassium hydroxide solution and probably CO_2, was produced in the oxidation of the hemochrome in the air and in the presence of high intensity visible light. Oxygen absorption was associated with both processes involving loss of nitric oxide from the pigment and oxidation of the resulting hemochrome. Several possible pathways have been suggested for the nitric oxide loss from denatured globin myohemochrome which could be of practical significance to the problem of discoloration. Denatured globin hemochrome shaken in the presence of free fatty acids undergoes a darkening not observed in light. Oxidation of the hemochrome may possibly be of significance in cured meat color deterioration.

Ramsbottom et al. (1951) concluded that lower light intensity, 20 foot-candles, discolored sliced, smoked, and table ready-to-eat

meat less rapidly than an intensity of 60 foot-candles in a given length of exposure.

Sliced bacon and cooked ham discolored as quickly under incandescent light as under florescent light. This study showed that sliced, cured, smoked and table ready meats were discolored to a lesser extent by a 36 hour exposure to ultraviolet rays than a similar exposure to florescent light at a 60 foot-candles intensity. However, with fresh meats the opposite was true. Fading of color was found to be associated with flavor deterioration in sliced, cured, smoked and table ready meats.

Rongey (1958) determined that no statistically significant differences in uniformity or stability of cured ham color were obtained between the two and seven day curing periods.

Henrickson et al. (1956) determined that ascorbic acid was more effective than sodium ascorbate in developing cured color, reducing the effect of light during the display period and retaining initial cured color.

Bacteria

Bacterial contamination results in a lowering of product quality and yield. Jensen and Hess (1941) made an extensive study of factors related to "bone sours" or putrefactive spoilage in hams. They reported the incidence of internal spoilage at that time to be in the range of 5 to 7 percent. In their investigations 18 different theories were considered, but no one factor was found to be responsible. They concluded that proper bleeding, adequate refrigeration, prompt handling

and strict general sanitation are all necessary in order to minimize losses and maintain adequate product quality.

Luminescence has been reported due to the growth of many different types of bacteria by Niven (1951). He concluded pigments produced by microorganisms were oxidation-reduction indicators as well as acid-base indicators. Bacteria no longer play an important part in cured meat color development, although certain lactic acid bacteria are responsible for the green discoloration in cured hams according to Niven (1951).

Evans and Niven (1951) isolated heterofermentative lactobacilli from discolored cured meats. They found these organisms required the addition of manganese and citrate for optimum growth, even in complex laboratory media. They found the lag phase could be shortened for some strains by addition of "tween 80" (sorbitan monooleate), folic acid and pyridoxine.

In an earlier experiment, Niven (1948) found greening organisms belong to the groups Lactobacillus and Linconostoc. They shared the common characteristics of being anerobic, acid tolerant, sugar fermenting, sometimes gas producing, and unable to reduce nitrates to nitrites. All greening organisms were found to grow at low temperatures (as low as 38° F.), be tolerant to salt, produce hydrogen peroxide when grown in the presence of air, and produce gas. Nonbacterial greening was found due to the use of aluminum smoke sticks and to metallic copper from the stuffing machine. Niven concluded greening can be

prevented by proper sanitation of equipment and plant facilities as well as proper meat handling.

Kelly (1964), in an experiment designed to study the relationship of ham souring to internal temperature prior to curing, found that hams chilled at an internal temperature of 1° C. prior to curing had less spoilage than hams with no chilling (38 to 40° C.) or chilled to 8 or 16° C. Also, he reported ham placed in cure after chilling to 1° C. had the highest percent salt. Moisture content for the hams was not affected by temperature.

In an experiment conducted to determine the effect of microorganisms found in commercial cover pickle on the color development in cured ham, Kalle (1955) recognized three organisms which when isolated reduced reaszurin and litmus milk but failed to reduce nitrates, were salt tolerant and grew best at 21° C. The yeasts, bacilli and streptococci, found to predominate in the commercial pickle did not produce CO_2 when grown in lactose or glucose fermentation tubes. The organisms improved the color by reducing the oxidation-reduction potential of the meat during curing.

In a similar experiment Mundt et al. (1954) isolated spores of Clostridium sporogenes C. In sour meat maximal germination of spores was obtained within 6 hours at 35° C. Good germination occurred at 8 percent salt concentration, pH 5.3, and 37° C. but not at 4.4° C. Germination characteristics were not altered by holding spores for a 14 day period.

Data collected or developed in Swift and Company Research Laboratories by Greenburg and Silliker (1961) indicated toxin formation by Clostridium botulinum occurred in cured meats with no accompanying degradation of the product. This occurred in products containing 6.25, 7.09, and 7.12 percent brine. They concluded that in a perishable cured product the level of salt must be within the range wherein botulism toxin formation is attended by obvious organic breakdown (below 6.25 percent brine). Alternatively, the salt level may be such that toxin formation is inhibited (above 9 percent).

Recent research by Gough and Alford (1965) has indicated that conventional curing processes cannot be relied upon to prevent food poisoning strains of Clostridium perfringens in mild cured smoked ham. Pulliam and Kelly (1965) showed that potential food poisoning staphylococci were capable of surviving in prechilled hams which were cured for 14 days at 3° C. and then smoked. Higher bacterial counts were reported by these workers for unsmoked, prechilled, processed, cured hams than in uncooked conventionally processed cured hams. Barbe et al. (1966) reported comparable enumerations for uncured rapid processed and conventionally processed hams but showed significantly ($P<.05$) greater reduction in the aerobic flora when rapid processing techniques were employed.

Barbe and Henrickson (1967) in an extensive examination of the bacteriology of rapid cured hams reported bacteria isolated from prechilled, cured, cooked samples represented seven genera. A marked decrease in incidence due to curing and cooking was noted for all

isolates except Bacillus. The decrease was mainly attributed to exposure of the heat sensitive organisms to the thermal effects, toxic curing ingredients, and low pH. In addition, the rapidity of the application of these combined lethal factors should prevent normal exponential growth. The increase noted in spore forming bacilli is attributable to in-process contamination during the boning and curing manipulations of the individual hams.

The exhaustive investigations of Smith et al. (1952) showed that thermoduric characteristics for bacillus species cannot be considered identical due to variation in the maximum and minimum growth temperatures of certain mesophilic strains.

Riemann (1963) inferred that bacilli are more common to conventionally processed meats than any other genera because of their wide resistance to thermal processing.

Silliker et al. (1962) found that nonpathogenic strains of enterococci and micrococci have a higher order of heat resistance than staphlococci.

Jones (1952) stated that pH below 4.5 inhibited all bacteria with one or two exceptions. The bacteria were not necessarily destroyed but may have remained dormant.

Callow (1947) stated that pH was 5.7 to 6.0 when rigor was complete. His discussion noted that an optimum pH for bacterial nitrate reduction in a curing brine was 5.9 to 6.0.

Heating and Smoking

The heating of cured meats is a very critical process. For example, Draudt et al. (1960) reported there was only a 5 to 10° F. difference between the temperature at which color fixation and undesirable rendering occurs. The smoking operation comprises only a 2 to 8 hour portion of the usual 12 to 24 hours required for heating cured meat items.

Draudt (1963) in a complete review of meat smoking processes stated, "Smoke is produced commercially in the U.S. by three methods: burning dampened sawdust, burning dry sawdust continually and by friction." The function of smoke on cured meat as reported by Draudt (1963) is more than producing the desirable flavor and color of smoked products. It contributes substantially to preservation by acting as an effective antioxidant and bacteriostatic agent as well as providing a protective film on the surface of smoked products. In Draudt's review he found that flavor was somewhat comparable no matter what source of hardwood, although he indicated conifer woods are not considered suitable for smoking food in the U.S. He also found the flavors of conventionally smoked food and electrostatically smoked food have been compared by a number of authors. In an evaluation of the findings, he found it remarkable that substantial differences in flavor have not been reported for electrostatically smoked products. This may be due to the relatively low sensitivity of individuals to smoke flavor.

In ending the review Draudt (1963) proposed the question "What is smoke?" It is still incompletely answered and additional work is needed.

Parker (1952) demonstrated that rapid chilling of hams (32° F. and 80 percent relative humidity) to 60° F. or lower after removal from the smokehouse resulted in reduced drip loss and shrinkage during storage and subsequent cooking.

The general trend in consumer preference is toward smaller sized ham roasts. In this study separating whole hams into parts was compared to the whole ham and the subsequent yield and organoleptic traits were evaluated. In reviewing the literature all factors which influence yield and organoleptic traits in a country style ham were explored.

METHODS OF PROCEDURE

Data for this project were collected from the hams of 66 crossbred hogs, 31 barrows and 35 gilts, from the South Dakota State University Swine Unit.

After the individual pigs reached a weight of 210 pounds, they were transported to the holding facilities of the South Dakota State University Meat Lab. Each pig was given a 24 hour shrink with water but without feed.

Slaughter and Cutting Procedure

All pigs were slaughtered by the South Dakota State University Meat Lab personnel. The carcasses were chilled for at least 48 hours at a temperature of 36° to 38° F. Wholesale cuts were made according to the procedure outlined in the Proceedings of the Fifth Annual Reciprocal Meat Conference by Cole (1952). Trimming was completed for each cut according to the methods of Gee (1967). The trimmed ham from the left side was boned by the method also outlined by Gee (1967) and weighed to the nearest one-tenth pound and frozen until a later date. The trimmed ham from the right side was boned by first loosening the meat around the aitch bone and removing the aitch bone as in the normal manner. Then the ham was placed on the table with the sirloin tip area facing up and split following the seam separating the sartoris and pectineus from the vastus intermedius and vastus medialis. This split then allowed the muscle surrounding the femur to be loosened, and the femur to be removed. The patella was then removed and the boneless

ham laid on the table fat side down in the open position. The ham was then split into top and bottom halves by finding the seam that separates the semimembranosus from the semitendinosus and using it as a guide to make a cut parallel to the outside of the ham thereby separating the ham into two uniformly shaped parts. These parts were then labeled top containing the following muscle systems: (1) semimembranosus, (2) adductor, (3) gracilis and (4) sartoris, and the bottom containing the following muscle systems: (1) semitendinosus, (2) biceps femoris and (3) sirloin tip muscles. The parts were then weighed to the nearest one-tenth pound and frozen until a later date.

This study was divided into six trials each involving 33 pieces or 11 pairs of hams (left whole ham, right top and bottom roasts). Trial 3 was later omitted during the analysis because of a difference in weights taken.

Pumping

The hams selected for each trial were taken from the freezer and allowed to thaw at 36° to 38° F. in the cooler. When they reached an internal temperature of 38° F., they were exposed to room temperature, unwrapped and prepared for pumping.

Each piece was pumped with a 50 percent commercial (Ottens) quick salt cure until it could not hold any more brine. Pumped weight was recorded to the nearest one-tenth pound, and the pieces were placed in a curing vat containing a 40 percent salt solution. The hams were immersed in the cover pickle for ten days at 36° to 38° F.

and were repacked in the pickle every three days. Following removal from the pickle, the hams were drained, rolled, and hand tied.

Heating and Smoking Procedure

The rolled and tied boneless hams were placed in stockinettes. The weight to the nearest one-tenth pound was recorded as "smokehouse in" weight. Uniform surface exposure to smoke and heat was maximized by hanging the rolled pieces from hooks in the smokehouse. Six hams, two of each type chosen at random, were monitored for precise measurement of internal temperature change during smokehouse heating by inserting a 12 inch thermocouple lead from a Speedomax Model W Multipoint Recorder.

The smokehouse was closed and the heating and smoking unit turned on. The hams were heated and smoked until they reached an internal temperature of 142° F. plus or minus 4° F. Hams were then removed from the smokehouse and hung on meat trees to cool to an internal temperature of 60° F. "Smokehouse out" weight for each piece was obtained and recorded at this time.

Color

In all but the first trial, a one-inch slice from the center of each piece was cut and labeled for color measurements. The area measured in trial 2 consisted of the semimembranosus (location I) and biceps femoris (location II) in the left ham piece, the semimembranosus (location I) and adductor (location II) in the top ham piece and the biceps femoris (location I) and semitendinosus (location II) in the

bottom ham piece. In the other four trials only location I was measured and recorded under average color determinates on the data sheet. Tristimulus Munsell color notations were obtained by using a photovolt reflectance meter. The readings were taken on one-inch ham slices approximately one hour after cutting. The reflectance meter was standardized prior to each series of readings using a 5R/7/2 Munsell color chit. The reference points for the amber, green and blue filters were 41.5, 35, and 38, respectively. The photoelectric cell was returned to the Munsell standard chit after each four readings to assure that the galvanometer was on the reference point. The values obtained from these three readings, one with each filter, on each ham slice were then inserted into the formula outlined by Hunter (1942) and the x and y values calculated. These were plotted on the Munsell value charts to determine the correct hue and chroma notations. When the value notations were greater than plus or minus 0.1 from a whole number, the hue notation and chroma notation were plotted on the two Munsell charts that bracketed the value notation and exact hue notation and chroma notation determined by interpolation. The three dimensions of color hue, value and chroma were analyzed as separate components. After color data were obtained, each ham slice was properly labeled, wrapped and frozen for later organoleptic and palatability tests.

Cookery, Shear and Organoleptic Evaluation

Ham slices used for palatability tests were thawed at room temperature prior to cooking. They were unwrapped and placed on

aluminum foil in a preheated 225° F. oven and heated to an internal temperature of 160° F. measured with a thermometer placed in the center of the ham slice. A one-inch core was removed from the semimembranosus in the left and top ham slices and from the biceps femoris of the bottom ham slices for shear evaluation. Thin (1/8") slices were cut from the remainder for organoleptic scoring. These slices were placed on preheated plates which were assigned to specific panel members by a coding system. Each plate was divided into six numbered areas and a slice of each sample was distributed to one of these areas in a predetermined order. An individual sample was not placed on the same area of each plate, but sample identification was maintained using this technique. As soon as a plate was filled, it was covered with a paper plate to reduce sample moisture loss and cooling.

The panel was composed of six members, all experienced in organoleptic testing of meat. Immediately upon receiving their samples, judgment was made on the lean meat color intensity and desirability and recorded on a hedonic scale from one to eight with 1, dark red; 2, red; 3, light red; 4, dark pinkish red; 5, light pinkish red; 6, dark pink; 7, pink; and 8, light pink. The juiciness, saltiness, tenderness and desirability of flavor were also scored using the eight point hedonic scale described by Pergam and Pilgrim (1957). The score sheet used by each panel member is shown in figure 1. The panel score sheet is shown in figure 2.

Name _____

Date _____

SCORE CARD
for
TASTE PANEL EVALUATION

	Color	Tenderness	Flavor	Saltiness	Juiciness
1.	Dark red	Extremely tender	Desirable	Extremely salty	Extremely juicy
2.	Red	Very tender	Desirable	Very salty	Very juicy
3.	Light red	Moderately tender	Desirable	Moderately salty	Moderately juicy
4.	Dark pinkish red	Slightly tender	Desirable	Slightly salty	Slightly juicy
5.	Light pinkish red	Slightly tough	Undesirable	Slightly bland	Slightly dry
6.	Dark pink	Moderately tough	Undesirable	Moderately bland	Moderately dry
7.	Pink	Very tough	Undesirable	Very bland	Very dry
8.	Light pink	Extremely tough	Undesirable	Extremely bland	Extremely dry

REMARKS:

Figure 1. Score card for taste panel evaluation.

Date _____ PANEL SCORE SHEET Project _____

Sample No.						
Sample Date						
Sample ID	A	B	C	D	E	F
Trait[a]	T F J S C	T F J S C	T F J S C	T F J S C	T F J S C	T F J S C
Panel Members						
1	1 _____	2 _____	3 _____	4 _____	5 _____	6 _____
2	2 _____	3 _____	4 _____	5 _____	6 _____	1 _____
3	3 _____	4 _____	5 _____	6 _____	1 _____	2 _____
4	4 _____	5 _____	6 _____	1 _____	2 _____	3 _____
5	5 _____	6 _____	1 _____	2 _____	3 _____	4 _____
6	6 _____	1 _____	2 _____	3 _____	4 _____	5 _____
7	1 _____	2 _____	3 _____	4 _____	5 _____	6 _____
8	2 _____	3 _____	4 _____	5 _____	6 _____	1 _____
9	3 _____	4 _____	5 _____	6 _____	1 _____	2 _____
10	4 _____	5 _____	6 _____	1 _____	2 _____	3 _____
TOTAL	_____	_____	_____	_____	_____	_____
AVERAGE	_____	_____	_____	_____	_____	_____

[a] T = Tenderness, F = Flavor, J = Juiciness, S = Saltiness and C = Color.

Figure 2. Taste panel score sheet.

The Warner-Bratzler shearing strength apparatus was used to objectively measure the ham tenderness. Results were expressed as the pounds of mechanical force required to shear a cooked meat cylinder one inch in diameter. The value reported for each ham slice was an average of two readings made on the one-inch meat core taken after cooking. All shears were made on each core as soon as possible after the ham slices were removed from the oven.

Statistical Analysis

Data were analyzed by finding differences between each variable for the whole ham (left) compared with the sum of the parts (right). These data were placed on IBM cards and the 1620 data processing system was used to compute mean differences and sample standard deviation differences.

To test for significant differences between the two techniques of processing hams, t values were computed using the mean differences and sample standard deviation differences.

RESULTS AND DISCUSSION

Yield was the major variable studied in this experiment. Processed meat product yield is important to the consumer, retailer and processor in that they all benefit from optimal yield or minimum shrinkage. Within quality brackets the amount of product sold in relation to the fresh or "green" product weight has a major influence in determining the price and profitability of a product. An evaluation of differences in yield and organoleptic traits between whole boneless hams as compared to whole hams split into top and bottom parts was undertaken in this study. Therefore, the weight change differences throughout the processing cycle or percentage differences between the whole ham as compared to the parts are discussed. The paired t values for each trait evaluated are presented in table 1.

Yield

In trial 1, all three yield factors considered, pumped weight, smokehouse in weight and smokehouse out weight, were not significantly different in hams processed whole or in parts.

The difference in pumped weight was highly significant in trial 2, with the parts weighing more or taking more brine than the corresponding whole ham. The difference in weight entering the smokehouse (smokehouse in weight) was also highly significant with the parts weighing more although the difference in smokehouse out weight (hams cooled to 60° F.) was not significant. In the finished product, the

TABLE 1. PAIRED t VALUES TO TEST SIGNIFICANCE BETWEEN THE DIFFERENCES OF THE PARTS SUBTRACTED FROM THE WHOLE

	Trial number					Underlined value indicates
	1	2	4	5	6	
Green wt.	.498	.4659	.3367	.6291	.5590	Parts--weigh more
Pumped wt.	.724	4.66**	1.7252	3.20**	4.14**	Parts--weigh more
Smokehouse in wt.	1.68	2.815**	1.174	1.613	3.45**	Parts--weigh more
Smokehouse out wt.	.1975	1.023	.7324	.1737	.2748	Parts--weigh more
Shear I		2.19	2.01	.8968	1.423	Parts--less tender
Shear II		1.525	.9602	.2608	1.732	Parts--less tender
Shear av.		1.643	1.419	.3179	1.393	Parts--less tender
Panel tenderness		.4699	.0360	.1375	.1571	Parts--less tender
Panel juiciness		.93116	2.51*	1.495	.2748	Parts--less juicy
Panel flavor		1.294	1.214	1.49	.4307	Parts--less desirable
Panel saltiness		2.578*	.8856	.9287	.9340	Parts--less salty
Panel color		3.318**	2.395*	2.017	1.537	Parts--darker color
Hue I		2.316*				Parts--lighter colored
Hue II		.9203				Parts--lighter colored
Hue av.		1.569	1.667	.6698	.6881	Parts--lighter colored
Value I		2.10				Parts--lighter colored
Value II		1.293				Parts--lighter colored
Value av.		.1096	10.34**	.2699	.9717	Parts--lighter colored
Chroma I		3.58**				Parts--more intense
Chroma II		.7898				Parts--more intense
Chroma av.		1.212	.9950	.0724	.1892	Parts--more intense

* Significant at the $P<.05$ level.
** Significant at the $P<.01$ level.
Hue - color, Value - degree of grayness, whiteness or blackness, Chroma - intensity of color.

parts still weighed slightly more than the whole ham (table 2). The whole ham (the left) when compared to the right separated into parts and expressed as percentage of green weight had 2.95 percent more weight loss than the parts.

TABLE 2. PERCENT OF GREEN WEIGHT YIELD

Trial number	Ham pairs	
	Left (whole)	Right (parts)
1	85.8	86.7
2	87.4	90.3
3[a]	86.6	87.2
4	90.3	89.4
5	91.0	92.7
6	88.6	87.1
Av.	88.3	88.9

[a] Final yield weights taken after additional 24 hour chill.

Trial 3 was omitted from the statistical analysis.

In trial 4, differences in weight between whole hams and the parts were not significant.

Pumped weight differences in trial 5 were highly significant ($P<.01$) with the parts weighing more than the whole ham. All the other differences in weight were nonsignificant at the $P<.05$ level.

In the sixth trial both pumped weight and smokehouse in weight differences were highly significant ($P<.01$) indicating the parts took on more brine than the whole ham from the same pig.

In all five trials the parts were physically able to hold more pickle than the whole ham. This may have been due to more uniform

distribution and diffusion of pickle into a smaller sized ham by the stitch pumping technique. The next weight taken in the cycle was the weight of the ham after soaking in the cover brine for 10 days. Again, in all the trials the parts weighed more, indicating they were not only able to be pumped to a greater weight but also retained the pickle solution in the cover brine. Lower paired t values indicated that weight differences between whole and parts were not as large as they were at the pumped stage.

In the next step the hams were placed in the smokehouse for a period of 22 to 24 hours or until the pieces reached an internal temperature of 142° F. plus or minus 4° F. In table 3 average mean temperatures for the whole hams and the parts are related with time in the smokehouse. The table demonstrates that the temperature of the parts increased more rapidly, reached a plateau, and finished within 4° F. of the corresponding whole ham.

In the final analysis the ham pairs showed no significant weight differences after the heating and smoking cycle. This suggested that although the parts were able to take on more brine and hold this brine during the curing cycle more brine weight was lost in the smokehouse as drip or evaporation than in the whole ham.

Greater weight loss of the parts may be due to the larger surface area exposed to drying in the heating phase. Under the processing conditions used, the muscle tissue or meat may be capable of holding only a certain maximum level of moisture. Since the final yields in all trials were similar for both whole and split hams, the

TABLE 3. MEAN INTERNAL TEMPERATURES FOR WHOLE HAMS AS COMPARED TO THE PARTS FOR FOUR TRIALS

Time	Parts	Whole
0 hr.	46.0° F.	44.0° F.
2 hr.	69.6° F.	58.6° F.
4 hr.	90.0° F.	78.0° F.
6 hr.	105.3° F.	96.0° F.
8 hr.	118.0° F.	111.3° F.
10 hr.	127.3° F.	122.0° F.
12 hr.	133.6° F.	128.6° F.
14 hr.	135.8° F.	133.6° F.
16 hr.	137.6° F.	135.6° F.
18 hr.	138.8° F.	137.3° F.
20 hr.	141.8° F.	139.6° F.
22 hr.	142.8° F.	142.0° F.
23 hr.	143.3° F.	142.3° F.

maximum moisture limit may have been approached. The parts would naturally lose more moisture under such conditions since more moisture was added to the parts during the curing process.

The percent of green weight or final processing yields are presented in table 2 for all six trials. The whole hams averaged 88.3 percent in yield compared to 88.9 percent for the parts, indicating there was very little difference between final yield of processed ham, whole or in parts.

In this study yield differences may have been nonsignificant because of a drying level established in the smokehouse. The parts took on more brine and therefore weighed more upon entering the smokehouse than the whole hams. Upon heating and smoking, they lost more water or weight than did the whole ham but because of the higher pumped weight had equal or superior final yield. There may be a relationship between

percent pump and final smokehouse yield. In future studies it would be advantageous to compare different pumping percentage levels to determine which level would provide maximum yield out of the smokehouse.

Organoleptic Traits

Average mean values for all panel evaluated organoleptic traits are presented in table 4.

Tenderness. Differences in tenderness between hams processed whole or in parts were determined objectively using the Warner-Bratzler shearing apparatus in four of the trials. The paired t values computed from the differences were not significant and are listed in table 1. Subjective tenderness scores resulting from taste panel appraisal of samples from hams processed whole or in parts were not significantly different (table 1).

When correlations were computed between tenderness and seven other factors studied (table 5), the correlations were very low with the highest being between tenderness and flavor ($r = 0.32$).

Juiciness. Juiciness scores were assigned by the taste panel members and differences analyzed by the same procedure as the other traits are included in table 1. Juiciness differences within pairs were not significant in trials 2, 5, and 6; although in trial 4 the parts were significantly ($P<.05$) less juicy than the whole ham. In general, the parts were slightly less juicy than the whole ham.

TABLE 4. PALATABILITY, SHEAR FORCE, AND COLOR MEANS FOR HAM SLICES FROM PAIRED HAMS, ONE WHOLE AND ONE SEPARATED INTO PARTS

Trial[a]		Panel color[b]	Panel juiciness[c]	Panel flavor[c]	Panel saltiness[c]	Panel tenderness[c]	Shear value[d]
2	whole	4.79	4.16	2.83	4.27	2.86	10.10
	parts	4.17	3.92	3.13	3.64	3.32	7.60
3	whole	3.83	4.15	2.80	3.83	3.01	9.32
	parts	3.72	3.61	2.83	3.65	2.75	4.68
4	whole	4.50	3.18	3.01	3.91	2.71	9.37
	parts	3.63	3.66	2.83	3.58	2.62	7.50
5	whole	4.13	3.51	2.50	3.57	2.77	7.33
	parts	4.52	3.72	2.67	3.47	2.78	6.62
6	whole	4.01	3.31	2.50	3.52	3.13	8.54
	parts	4.30	3.27	2.43	3.38	3.07	5.17
Average							
	whole	4.25	3.66	2.69	3.82	2.90	7.11
	parts	4.07	3.64	2.78	3.54	2.91	6.23

[a] Mean values were not measured in trial 1.
[b] A score of 8 equals light pink, 1 equals dark red.
[c] A score of 1 equals extremely juicy, desirable flavor, extremely salty, extremely tender; 8 equals extremely dry, undesirable flavor, extremely bland, extremely tough.
[d] Expressed in pounds, the greater the number of pounds the less tender the slice.

TABLE 5. CORRELATION COEFFICIENTS BETWEEN VARIOUS YIELD AND ORGANOLEPTIC TRAITS

	% of green weight change from maximum	Pump to smoke	Green to smokehouse change	Final yield as a % green weight	Salti-ness	Flavor	Tender-ness
% pump of green weight	0.76	-.72	0.83	-.09	-.37	-.16	0.06
% of green weight change from maximum		-.51	0.66	0.55	-.27	-.23	-.005
Pump to smoke			-.21	-.01	0.22	0.17	-.08
Green to smokehouse change				-.15	-.35	-.09	0.02
Final yield as a % green weight					0.05	-.16	-.11
Saltiness						0.23	-.07
Flavor							0.31

Flavor. Taste panel scores suggested that there was no difference between the flavor of the whole vs. the parts. The analysis is presented in table 1. In all four trials the paired t values were not significant.

The correlations between flavor and seven other factors presented in table 5 were generally low accounting for very little of the variability. The highest r value was 0.31 between flavor and tenderness.

Saltiness. Taste panel scores indicated that only in trial 2 were the parts significantly ($P < .05$) more salty than the corresponding whole ham. In the other three trials there were no significant differences as indicated in table 1.

In table 5 correlation coefficients between saltiness and percent pump of green weight displayed the highest r value of -.37.

A relationship between saltiness and the conditions of the ham, whole or parts, was considered possible as the trials progressed. Since the parts took more brine during the curing phase and lost more weight in the form of moisture during smoking and heating than the whole ham, a higher salt concentration was anticipated in the parts. Although the trend was for higher saltiness scores in the parts, significance was obtained in only one trial. Further work in this area should include chemical analysis of salt levels to supplement taste panel data.

Color

The three dimensions of color, in general, indicated that the parts were a lighter pink color as determined objectively by the photovolt reflectance meter. These data are presented in table 1. The hue notations indicated the parts were lighter colored but not significantly different. The difference in value notation (brightness) was highly significant in trial 4 with the parts being of a lighter color. The value notation differences in the other three trials were nonsignificant. The average chroma notation differences were not significant between ham pairs. Subjective color evaluations by taste panel members also indicated the parts were a lighter color in two of the four trials. Differences were very highly significant in trial 2 ($P<.01$) and significant ($P<.05$) in trial 4. However, the trend was reversed in trials 5 and 6 where the parts were slightly darker than the whole ham.

In America today there is a growing trend to a smaller sized family unit coupled with a rising standard of living. These factors have helped to cause the consuming public to seek more variety and convenience items when purchasing meat.

The data collected and analyzed in this study suggest that it is physically possible to separate today's heavier muscled hams into top and bottom parts, thereby producing a compact, smaller sized (3 to 5 pounds) ham to meet the demand of today's smaller sized family unit.

The data have shown there are no significant differences between final yield in hams processed whole or as parts. Also, there are no

significant differences or trends in organoleptic traits as measured subjectively and objectively in whole hams when compared to the parts.

It therefore can be concluded that it is both practical and economical to process hams as parts as viewed from the standpoint of the producer, processor, retailer and the consumer. By separating whole hams into parts we can satisfy the need of the consumer and provide another method of merchandising to the retailer and the processor.

measurement by the photovolt reflectance meter. The ham slices were then frozen for later organoleptic evaluation.

Ham slices used for palatability tests were allowed to thaw at room temperature prior to cooking. Each ham slice was placed on aluminum foil in a preheated 225° F. oven and heated to an internal temperature of 160° F. When the ham slices reached 160° F., a one-inch core sample was removed for shear evaluation by the Warner-Bratzler shearing apparatus. The rest of the ham slice was cut into thin (1/8") slices to use in organoleptic scoring. The panel composed of six members made judgment on desirability of lean meat color, juiciness, saltiness, tenderness, and desirability of flavor using the eight point hedonic scale.

Data were placed on IBM cards and the 1620 data processing system used to compute mean differences and standard deviation differences. This information was used to compute t values to test for significant differences between the two techniques of processing hams.

This project evaluated the merit of separating whole hams into top and bottom parts and subjecting them to the curing and smoking process. Their subsequent yield and organoleptic qualities were then evaluated to determine if it was feasible to process hams in this manner. Mean differences between paired hams from the same hog, one processed normally and the other divided into top and bottom parts, were computed and used to make t tests for significant differences.

The major goal in this project was to measure and compare the final product yield of the hams processed in the above manner. There was essentially no difference between the whole ham and the ham

separated into parts, indicating it is possible to economically process whole hams by separating them into parts.

Taste panel results indicated no differences between tenderness and flavor. Furthermore, in trials 4 and 6 no differences were indicated for the other traits evaluated by the taste panel (juiciness, saltiness and color).

Only in trials 2 and 4 did any significant differences exist in trials evaluated subjectively. In trial 2, the whole hams were lighter colored ($P<.01$) and less salty ($P<.05$) than the parts. In trial 4, the parts were significantly ($P<.05$) less juicy and lighter in color than the whole hams as evaluated by the taste panel members. Objectively, the color measurements agreed with the taste panel in all trials.

There appeared to be no significant difference between tenderness scores of ham pairs processed differently as evaluated objectively by the Warner-Bratzler shearing apparatus or subjectively by panel members.

The time-temperature relationship showed the whole hams heated more slowly but both hams finished the process at approximately 23 hours.

In this study, separating hams into top and bottom parts appeared to be another method of merchandising today's heavier muscled hams to a smaller size family unit that is seeking a more convenient, less expensive country style ham.

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